ANALYSIS OF THE BLACK-CAPPED VIREO AND WHITE-EYED VIREO NEST PREDATOR ASSEMBLAGES

A Thesis

by

TARA JENISE CONKLING

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2010

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Chair of Committee,	Michael L. Morrison
Committee Members,	Bret Collier
	William Rogers
Head of Department,	Thomas Lacher Jr.

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ABSTRACT

Analysis of the Black-capped Vireo and White-eyed Vireo Nest Predator Assemblages.

(May 2010)

Tara Jenise Conkling, B.S., Kansas State University

Chair of Advisory Committee: Dr. Michael Morrison

Predation is the leading cause of nest failure in songbirds. My study identified nest predators of black-capped vireos and white-eyed vireos, quantified the activity of potential predator species, examined the relationships between vegetation and nest predators, and examined the relationship between nest predation and parasitism by brown-headed cowbirds. In 2008 and 2009 I monitored black-capped and white-eyed vireo nests on privately-owned properties in Coryell County and black-capped vireo nests on Kerr WMA in Kerr County and at Devils River State Natural Area in Val Verde County (2009 only). I monitored vireo nests using a video camera system to identify predators and nest fate. I also collected at-nest vegetation measurements including nest height, distance to nearest habitat edge, and nest concealment. Additionally, I sampled potential predator activity at a subset of black-capped vireo and white-eyed vireo nests in Coryell County using camera-trap bait stations and herptofaunal traps.

I monitored 117 black-capped vireo nests and 54 white-eyed vireo nests. Forty-two percent of black-capped vireo and 35% of white-eyed vireo nests failed due to

predation. I recorded >10 total predator species and 37 black-capped vireo and 15 white-eyed vireo nest predation events. Snakes (35%) and cowbirds (29%) were the most frequently identified nest predators; however, major predator species varied by location. I observed no significant relationship between nest fate (fledge vs. fail) and nest concealment or distance to edge for either vireo species. Nest height, concealment and distance to edge may relate to predator species in Coryell Co. for snake species, and Kerr for avian species. Additionally, I observed no difference between the predator activity and the fate of the nest.

Both vireos have multiple nest predator species. Additionally, multiple cowbird predations demonstrate this species may have multi-level impacts on vireo productivity, even with active cowbird management. Vegetation structure and concealment may also affect predator species. However, the activity of other predator species near active nests may not negatively affect nest success.

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CHAPTER I

INTRODUCTION

NEST PREDATION

Predation is the leading cause of nest failure in songbirds (Martin 1993, Grzybowski 1995, Schmidt and Whelan 1999). Understanding the relationship between nest success and predation is necessary to gain knowledge of this limiting factor and to develop effective conservation plans in the future, especially for threatened and endangered avian species. Despite research indicating that predation is a major limiting factor, only a few studies directly address nest predators or the relationships between predator assemblages and habitat (Sovada et al. 2000, Smith 2004) or predators and habitat type (Kuehl and Clark 2002, Thompson and Burhans 2004, Stake et al. 2005, Marzluff et al. 2007, Thompson 2007). Predator assemblages may also be altered by different land use practices or fragmentation of the landscape (Thompson 2007, Sperry et al. 2009), which may affect composition of the predator assemblage (Chalfoun et al. 2002). Since spatial and temporal patterns of predators may drive reproductive success for avian species (Cain et al. 2006, Sperry et al. 2008, Benson et al. 2010), understanding effects of habitat characteristics on avian nest predator assemblages is an important step to avian conservation.

Until recently, studies focusing on predators were limited due to technology.

This thesis follows the style of the Journal of Wildlife Management.

Often, predator identification was based solely on incidental sightings or inferences from remains of nest contents (Martin 1993, Grzybowski 1995, Schmidt and Whelan 1999), which can lead to inaccurate identifications (Williams and Wood 2002). New monitoring methods utilizing still cameras (Cutler and Swann 1999, Swann et al. 2004) and video cameras for continuous surveillance (Delaney et al. 1998, Stake and Cimprich 2003, Thompson and Burhans 2003, Stake et al. 2004, Pierce and Pobprasert 2007) allow for enhanced predator identification.

Use of more accurate identification methods has shown the predator assemblage, much like the level of edge effects, depends on region and spatial characteristics of the habitat. Small and medium sized mammals are dominant predators in fragmented forests (Stake and Cimprich 2003, Thompson and Burhans 2003, Schaefer 2004, King and DeGraaf 2006), whereas snakes are dominant predators in southern shrub habitats (Thompson, 2007). An introduced predator in the southern United States ,the red imported fire ant (*Solenopsis invicta*), is known to swarm and kill hatching birds and nestlings of multiple avian species (Kopachena et al. 2000, Allen et al. 2001, Stake and Cimprich 2003, Allen et al. 2004, Campomizzi et al. 2009). In addition, many songbird species throughout the western half of the United States have reduced nest success resulting from parasitism and nest predation by the brown-headed cowbird (*Molothrus ater,* hereafter "cowbird") (Stake and Cimprich 2003). Cowbirds are a parasitic-generalist species that remove host eggs (and occasionally nestlings) and lay their own eggs in the host nest (Elliott 1999). Understanding these dominant and co-existing predators and their relationships with the surrounding habitat and prey species is an

essential component for endangered species management. This is especially true in Texas, where multiple species (snakes, corvids, cowbirds, and fire ants) have been identified as major nest predators for endangered songbirds like the black–capped vireo (*Vireo atricapilla*), and a non-threatened congeneric, the white-eyed vireo (*V. griseus*).

The black–capped vireo is a federally endangered songbird (Ratzlaff 1987) whose numbers have declined due to habitat loss, habitat fragmentation, and parasitism by brown-headed cowbirds (Grzybowski 1995). The breeding range for black-capped vireos extends from western Oklahoma through central Texas and south to Coahuila, Mexico, although historically the range extended through much of Oklahoma into south-central Kansas (Grzybowski et al. 1994, Grzybowski 1995). Typical black-capped vireo breeding habitat is clumps of shrubby deciduous vegetation of irregular heights. These clumps cover 35–55% of the habitat and vegetation cover usually extends to ground level (Grzybowski et al. 1994, Bailey and Thompson 2007).

White-eyed vireos are a common species whose breeding range extends from Massachusetts to Florida, and west to Kansas through central Texas. Within the Edwards Plateau, trend data from the Breeding Bird Survey for 1987-2007 indicates a potential population increase (Leon River Restoration Project 2005, Institute of Renewable Natural Resources 2007,Sauer and Hines 2007). Typical white-eyed vireo breeding habitat is middle- to late-stage successional deciduous scrub, also containing variable undergrowth, shrubs, and taller trees, with dense foliage near ground level (Hopp et al. 1995). Within the study region, white-eyed vireos occupy habitat that is typically more overgrown than preferred black-capped vireo habitat. However, nest characteristics and

parental behavior of adult birds for both vireos are similar and territories of both species can overlap with no obvious conflicts (T. J. Conkling, personal observation).

Predator research regarding vireo species is limited. Stake and Cimprich (2003) used a video monitoring system on Ft. Hood in east-central Texas to examine nest predators at 142 black-capped vireo nests. Texas rat snakes (*Elaphe obsoleta lindheimeri*) and red imported fire ants accounted for 38% and 31%, respectively, of predation events in their study. Recent research has focused on temporal and spatial habitat use of rat snakes (Blouin-Demers and Weatherhead 2001*a,b*; Carfagno and Weatherhead 2006), including ongoing research on Ft. Hood (Sperry et al. 2008).

Limited studies have addressed the temporal and spatial activity patterns of other black-capped vireo predators. Fire ants may adversely affect nest success of breeding songbirds within the study region (Campomizzi et al. 2009). Additionally, ant seasonal activity patterns are strongly tied to soil temperature and peak foraging often occurs at ~29 degrees C in Oklahoma and Florida (Vogt et al. 2003), which coincides with the black-capped vireo breeding season from April through July in east-central Texas. Other than nest video collected at Ft. Hood or incidental observations at nests (Graber 1961, Grzybowski 1995) little or no information exists for black-capped vireo nest predation events or nest predators (snakes, avian species, mammals, or ant species) in any other region of the species' range. Black-capped vireo habitat covers a wide variety of ecotones, ranging from the Edwards Plateau dominated by regular rainfall and multiple *Quercus spp.* providing successional habitat to vegetation on the western boundary where xeric shrub habitat dominates the landscape. Given the change in environmental

conditions across the range, it is reasonable to expect that predator assemblage (and thus major limiting factors) may differ depending on location and vegetation. Understanding and identifying the black-capped vireo predator assemblage range-wide offers the opportunity to ensure that species management is effective wherever applied. There is no recorded information on white-eyed vireo nest predators (except incidental observations) in any previous published studies.

Additionally, limited black-capped vireo research has occurred on private lands. The majority of vireo data collected has occurred on military properties such as Ft. Hood and Ft. Sill in Oklahoma, and public-managed wildlife areas. However, since ~95% of land in Texas is privately owned (Texas Environmental Profiles, 2007), the vast majority of black-capped vireo habitat management must occur here. Research on private land is essential to determine if previous research on public lands where large bird populations exist is applicable on a larger spatial scale. If different land uses (e.g. military training vs. private ranching), predator culling on private lands, and other factors affect the composition or activity patterns of the predator assemblage then nest failure rates may differ, and alternative management plans may need to be considered. Additionally, it is important to understand impacts of habitat fragmentation on the predator assemblage. Although Ft. Hood and other public lands contain large patches of contiguous habitat, vireo habitat on private properties in the region is highly fragmented due to factors including roads, high fences, pastures, and removal of Ashe juniper (*Juniperus ashei*). The resulting fragmentation may affect predator presence or behavior, in turn altering avian nest success. Thus, research on private properties is an essential component of

endangered species management.

BROWN-HEADED COWBIRD IMPACTS

It is also important to understand the effects of brown-headed cowbirds on black-capped vireo nest predator activity and nest predation levels because cowbirds can cause nest failure through either nest parasitism or predation. Although some small-bodied songbirds recognize and reject cowbird eggs, black-capped vireos and white-eyed vireos both accept cowbird eggs laid in their nest (T. J. Conkling, personal observation). In these two species, presence of a cowbird egg usually means failure of the host clutch. Previous studies have shown that cowbirds will remove host eggs and host nestlings from black-capped vireo nests (Stake and Cavanagh 2001, Stake and Cimprich 2003).

To explain the relationship between nest parasitism and nest predation, it has been suggested that cowbirds either directly (the "cowbird predation" hypothesis) or indirectly ("cowbird facilitation" hypothesis) cause nest failure by predation in host species (Duncan and Jenkins 1998, Mullin and Cooper 1998). The predation hypothesis argues that female cowbirds depredate host nests located late in the nesting cycle to induce re-nesting by host species (and thus create future parasitism opportunities). It predicts that un-parasitized nests will fail more frequently than parasitized nests due to female cowbirds destroying nests. However, if female ranges overlap, the cowbird predation hypothesis predicts nest success of parasitized nests to be less than un-parasitized nests since there is a greater potential for different cowbirds to discover the same nest. The facilitation hypothesis predicts that the parasitism-predation relationship is due not to direct predation events by cowbirds, but rather that parasitism events attract

alternative predator species to the nest. Previous data collected within the RCS study region indicates that the proportion of depredated nests is higher if the nest has been parasitized (unpublished data). If this pattern holds true, the use of video surveillance at nests would help to determine if: a) the higher failure rates of parasitized nests are due to predation by female cowbirds with overlapping territories as predicted by the cowbird predation hypothesis and b) the presence of a cowbird predation event increases the likelihood of future nests at that site to be parasitized.

Although some research has shown an increased success rate with decreased numbers of cowbirds (Kosciuch and Sandercock 2008), little research on any avian species focuses on the potential effects of cowbird presence on predation levels by other nest predators in the area. Many potential nest predators within black-capped vireo habitat are visual predators (e.g. squirrels, corvids, and snakes) (Duncan and Jenkins 1998, Mullin and Cooper 1998). Parasitizing cowbirds may cause nest failure indirectly by increasing overall activity near the nest, thereby attracting these visual predators to the nest more readily than non-parasitized nests.

Trapping of brown-headed cowbirds is a common management practice throughout North America to control parasitism rates of passerines. It is essential for black-capped vireo conservation within the study region. Active cowbird trapping at 7-8 properties within Coryell County from 2007-2009 have reduced parasitism rates from 100% in 2006 to approximately 33% (unpublished data). In Kerr County, moderate cowbird trapping at Kerr Wildlife Management Area reduced black-capped vireo parasitism rates to 19% (T. L. Pope, personal communication). Intensive cowbird

trapping on Ft. Hood has reduced parasitism levels of black-capped vireo on base to <10% (Eckrich et al. 1999). However, despite the success of cowbird trapping at reducing nest parasitism rates, trapping for cowbirds may have unintended consequences if individual cowbirds are responsible for nest predation. Cowbirds appear to predate only nests that contain no cowbird eggs or offspring (Stake and Cavanagh 2001). If trapping reduces the instances of parasitism in black-capped vireo nests, a possible increase in the number of cowbird predation events may occur since fewer nests would have cowbird-related contents. Although addling of cowbird eggs in parasitized nests is possible to prevent the cowbird from hatching, there is no simple control method to prevent adult cowbirds from predating nests. This intensive trapping removes extra cowbird females, and reduces the potential for territorial overlap.

My results will further our understanding of nest predator assemblages on public and private land, leading to increased effectiveness of future recovery efforts for black-capped vireos.

CHAPTER II

AN ANALYSIS OF THE BLACK-CAPPED VIREO AND WHITE-EYED VIREO NEST PREDATOR ASSEMBLAGES

Predation is the leading cause of nest failure in songbirds (Martin 1993, Grzybowski 1995, Schmidt and Whelan 1999). However, rates of nest failure may not be consistent within a study area and may be largely dependent on species response to predation risk. Understanding the relationship between nest success and predation is especially true when dealing with threatened and endangered avian species who may respond differently to nest predation than common generalist species. Few studies have addressed nest predators or the relationships between predators and habitat type (Kuehl and Clark 2002, Thompson and Burhans 2004, Stake et al. 2005, Marzluff et al. 2007, Thompson 2007) or predator assemblages (Sovada et al. 2000, Smith 2004). Habitat fragmentation or different land use practices may alter predator assemblages (Thompson 2007, Sperry et al. 2009), which may affect composition of the predator assemblage (Chalfoun et al. 2002). Since spatial and temporal patterns of predators may drive reproductive success for avian species (Cain et al. 2006, Sperry et al. 2008, Benson et al 2010), understanding effects of habitat characteristics on avian nest predator assemblage is an important step for avian conservation. To date, no research has examined nest predation and predator activity in the context of co-occurring species, such as the federally endangered black-capped vireo (*Vireo atricapilla*), and a congener, the white-eyed vireo (*V. griseus*).

The black–capped vireo is a federally endangered songbird (Ratzlaff 1987) whose numbers have declined due to habitat loss, habitat fragmentation, and parasitism by brown-headed cowbirds (Grzybowski 1995). The breeding range for black-capped vireo extends from western Oklahoma through central Texas and south to Coahuila, Mexico, although the historic range extended through much of Oklahoma into south-central Kansas (Grzybowski et al. 1994, Grzybowski 1995). Typical black-capped vireo breeding habitat is clumps of shrubby deciduous vegetation of irregular heights covering 35–55% of the habitat; vegetative cover usually extends to ground level (Grzybowski et al. 1994, Bailey and Thompson 2007).

White-eyed vireos are a common species whose breeding range extends from Massachusetts to Florida, and west to Kansas through central Texas. Within the Edwards Plateau, trend data from the Breeding Bird Survey for 1987-2007 indicates a potential population increase (Sauer and Hines 2007). White-eyed vireo breeding habitat includes middle- to late-stage successional deciduous scrub, containing variable undergrowth, shrubs, and taller trees, with dense foliage near ground level (Hopp et al. 1995). Within the study region, white-eyed vireos occupy habitat at a later successional stage than preferred black-capped vireo habitat. However, territories of both species can overlap with no obvious conflicts (T. J. Conkling, personal observation).

Predator research regarding vireo species is limited. Stake and Cimprich (2003) used a video monitoring system on Ft. Hood in east-central Texas to examine nest predators at 142 black-capped vireo nests. Texas rat snakes (*Elaphe obsoleta lindheimeri*) and red imported fire ants (*Solenopsis invicta*) accounted for 38% and 31%,

respectively, of predation events in their study. Rat snake habitat use may be linked to vireo nest success (Sperry et al. 2009), while red imported fire ants, an introduced predator in the southern United States, can swarm and kill hatching birds and nestlings of multiple avian species (Allen et al. 2004, Kopachena et al. 2000, Stake and Cimprich 2003, Campomizzi et al. 2009).

In addition, many songbird species throughout the western half of the United States have reduced nest success resulting from parasitism and nest predation by the brown-headed cowbird (*Molothrus ater)*. Cowbirds are a parasitic-generalist species that remove host eggs (and occasionally nestlings) and lay their own eggs in the host nest (Elliot 1999). Presence of a cowbird egg means typically means failure of the host clutch for vireos. Previous studies have shown that cowbirds will remove host eggs and host nestlings from black-capped vireo nests (Stake and Cavanagh 2001, Stake and Cimprich 2003).

Trapping of brown-headed cowbirds is a common management practice throughout North America to control parasitism rates of passerines. It is essential for black-capped vireo conservation within the study area. Intensive cowbird trapping on Ft. Hood has reduced parasitism levels of black-capped vireo on base to <10% (Eckrich et al. 1999). While less effective, localized trapping on nearby private properties reduced parasitism on black-capped vireo nests from 100% to approximately 33% during 2006–2009 (T. J. Conkling, unpublished data).

Other than nest video collected at Ft. Hood or incidental observations at nests (Graber 1961, Grzybowski 1995) little or no information exists for black-capped vireo

nest predation events or nest predators (snakes, avian species, mammals, or ant species). For the white-eyed vireo, there is no previously published data on nest predators (except incidental observations).

Additionally, limited black-capped vireo research has occurred on private lands. Since ~95% of land in Texas is privately owned (Texas Environmental Profiles 2007), the vast majority of black-capped vireo habitat management must occur here. Research on private lands is essential to determine if results from previous studies conducted on public lands with large vireo populations are applicable elsewhere. If different land uses (e.g. military training vs. private ranching), predator culling on private lands, and other factors affect the composition or activity patterns of the predator assemblage then nest failure rates may differ, and alternative management plans may need to be considered. Additionally, it is important to understand impacts of habitat fragmentation on the predator assemblage. Although public properties contain large patches of contiguous habitat, vireo habitat on private properties in the region is highly fragmented due to roads, high fences, pastures, removal of Ashe juniper (*Juniperus ashei*), and other factors. The resulting fragmentation may alter predator presence or behavior, in turn altering avian nest success. Thus, predator knowledge is an essential component of endangered species management.

With this study, I sought to: 1) identify nest predators of black-capped vireos and white-eyed vireos, 2) quantify the temporal and spatial activity of potential predator species within the study area, and 3) examine the relationships between vegetation characteristics and the identified nest predator species (Table 2.1).

For my first objective, I predicted that frequency of predations by specific nest predator species would vary from data collected at Ft. Hood due to different land management strategies on private lands. I expected snake and ant predation levels to vary resulting from modified brush management and grazing practices on study sites. I also expected incidents of predation by brown-headed cowbirds to increase due to smaller-scale trapping efforts on private lands. For my second objective regarding the temporal and spatial predator activity of potential predator species within the study area, I expected that nest success would decrease with increased activity within the vicinity of the nest.

Based on vegetation characteristics, I predicted that predation events by fire ants (and other ant spp.) would decrease with increasing nest height, and not vary with any over vegetation variable such as concealment, since distance from ground would be the major factor limiting ant foraging efforts. However, I predicted predation events by all other species to increase with decreasing vegetation concealment at the nest and distance to edge of habitat patch. I expected mammalian predation events to decrease, while avian predation events would increase. Snake predation events would be unaffected by nest height and were expected to increase with proximity to edge.

Table 2.1. Predicted frequency of predation events at black-capped vireo and white-eyed vireo nests that are expected to increase (↑) or decrease (↓) with increasing nest height (m), increasing distance from nest to habitat edge (m) and increasing mean % concealment at the nest.

	Frequency of predation events		
	↑ Nest Height (m)	↑ Distance to edge (m)	↑ % Concealment (0-2m)
Ant Spp.	↓	↓	no difference
Avian Spp.	↑	↑	↓
Brown-headed cowbirds	↑	↑	↓
Mammals	↓	↓	↓
Snakes	↓	↓	↓

STUDY AREAS

I monitored black-capped vireo and white-eyed vireo nests on 11 privately-owned properties within Coryell County in east-central Texas during 2008 and 2009 from ongoing point-count surveys as part of a large-scale research initiative- the Leon River Restoration Project (LRRP), and later the Recovery Credit System (RCS). Both LRRP and RCS were designed to monitor occupancy, distribution and abundance trends of the black-capped vireo and golden-cheeked warbler (*Dendroica chrysosparia*) populations on private lands surrounding Ft. Hood to provide information for continued conservation and management efforts. Research has been ongoing since 2003 (Leon River Restoration Project 2005, Institute of Renewable Natural Resources 2007, Butcher et al. 2010). The study area occupies approximately ~140,000 ha and primary land uses include ranching, hunting, and farming. The topography consists of rocky limestone hillsides and mesas ranging in elevation from 200–500 m. Bordering the study area to the south is Ft. Hood. Occupying southern Coryell county and northern Bell County, Ft.

Hood contains the largest known populations of black-capped vireos; active monitoring of the populations has been ongoing since 1987.

METHODS

I located current and previously active black-capped vireo territories to use as study sites for nest monitoring through ongoing point count surveys for RCS, as well as historical territory locations. Sample units selected for surveying included all private lands active in either LRRP or RCS programs within Coryell County that contained historic or current black-capped vireo territories. Surveyed locations included both currently/historically occupied black-capped vireo habitat, as well as unoccupied patches that met criteria for black-capped vireo habitat (Graber 1961, Grzybowski 1995). I visited potential study sites at least once every 10 days in order to maximize the potential of detecting resident black-capped vireos (Ralph et al. 1991, Grzybowski 1995). On the LRRP and RCS properties containing active black-capped vireo territories I also identified active white-eyed vireo territories using the same methods.

Nest Searching and Video Monitoring. — I located nests for black-capped vireo and white-eyed vireo in each sample unit using behavioral observations of adult birds and systematic search techniques (Martin and Geupel 1993). If black-capped vireo were not present in historically occupied patches, I conducted nest searching solely for white-eyed vireo. I monitored active nests every 2–7 days to determine outcome (i.e., nest fledged ≥ 1 host young or failed). In addition, I utilized a video camera system to accurately identify predators and nest fate. The system consisted of a weatherproof bullet camera with a 1/3", 3.6mm lens and infrared lighting (Rainbow, Costa Mesa, CA) to record

night events placed near enough to the nest to capture all activity, but not disturb the birds (approximately 1-2 m). A 15-m cable connected the camera unit to a digital video recorder ([DVR], Detection Dynamics, Austin, TX) and a 12v 26ah battery (Batteries Plus, Hartland, WI). In 2008, I used 4GB SD memory cards and a time-lapsed recording of 5fps to maximize data storage on the DVR. I checked the camera system every 2–3 days to replace data cards and batteries as needed and left the camera in place until the nest fledged or failed. For 2009, I upgraded the data storage to 8 GB cards and supplemented battery power with 20 watt solar panels (Suntech, San Francisco, CA) to reduce the number of visits to the active territories. I attempted to place cameras at all nests that were in the incubation or nestling stage. Ten nests were not monitored by cameras due to equipment availability or nest failure (abandonment or depredation) prior to the camera setup visit.

Predator Activity Sampling.—I selected a subset of active nests of both black-capped vireo and white-eyed vireo within Coryell county as central points for sampling units to examine predator activity. I chose nests based on species (black-capped vireo nests had priority over white-eyed vireo nests) and availability of sampling equipment. Each sample unit consisted of an 80-m radius area centered on the location of the active vireo nest. The 80-m radius sampling area approximated the typical 1–2 ha territory size of black-capped vireos and white-eyed vireos (Grzybowski 1995, Hopp et al. 1995) and also standardized the sampling unit, since patch size among the study sites is highly variable (personal observation). I conducted predator activity sampling using 2 separate methods to sample for multiple potential nest predators. All predator sampling locations

were located within the sample unit, but still approximately 40 m from the nest, to reduce potential nest disturbance. To determine non-reptilian predator activity, I used 2 camera-trap bait stations consisting of an infrared digital game camera (Moultrie Feeders, Alabaster, AL) and a corresponding bait station. I placed the bait station on a tree approximately 1–2 meters above the ground (corresponding to average vireo nest height) and attached ¼ of a hot dog (generic brand) to the tree under a protective hail-screen cover to discourage bait removal. I surrounded the bait screen with 1/3 of a pest glue board (PIC Corporation, Orange, NJ) to detect visits by fire ants and to eliminate the potential for ants to swarm the bait since this would discourage other predator visits. The cameras were set to record a 5-second video clip plus 1 image at initial predator detection and then to record additional images and video if activity occurred after a 1 minute delay in the vicinity of the bait station. I visited stations once a week to replace the hot dog, digital camera card, and camera batteries (as needed).

For analysis of fire ant activity, I classified an index of activity within each sample unit as the percent of functioning bait stations that contained photographs or sticky trap evidence of that species. For all other potential predator species, I recorded time, date, and activity of the predator visit each time I detected a species in a video clip or picture. I classified activity based on species behavior. Activities included individuals visiting the bait station, attempting to remove bait, or incidental images where I observed the animal within the camera frame by the vicinity of the bait station. I only recorded detections as separate visits if they were >10 minutes apart to ensure predator species were actively moving within the nest vicinity before returning to the

bait station. All images from each camera were individually marked with the date, time, and temperature of each recorded event that allowed for identification of individual predators based on body markings. If multiple individuals visited the station within the 10 minute period, I recorded this as multiple visits per species. I calculated potential predator activity as the number of distinct visits per species over the total days the stations were active.

I sampled the herptofaunal predator assemblage using 1.22 m x 1.22 m x 0.46 m multiple-entrance funnel traps designed for capture of large snakes (Burgdorf et al. 2005), with slight modifications in the design to place 2 trap doors on opposite sides of the trap to reduce the need for direct handling of captured snakes. I placed traps so that the 4-15 m drift fences constructed of ¼" polypropylene mesh (Industrial Netting, Minneapolis, MN) extend in the 4 cardinal directions from each central funnel unit. I checked traps every 3-4 days and recorded species and estimated length (to the nearest 0.5m) for each captured individual. Topographical constraints (e.g., steep slope) limited the number of nests I was able to sample for herptofauna.

Vegetation Sampling.—I collected vegetation measurements at each nest location, camera trap, and herptofaunal trap location. Nest vegetation data collection only occurred after nests were no longer active. Vegetation measurements included vegetation maximum height at nest, distance and direction to nearest edges, slope, trap or nest substrate, trap or nest height, and percentage of visual obstruction by vegetation 1m from nest in the cardinal directions, above, and below nest. I measured additional concealment data using a profile board at 7 m from nest location from each of the

cardinal directions (Guthery et al. 1981). Data collected included species identification, average and maximum height, continuous coverage values. I analyzed vegetation data by examining box plots, scatter plots, histograms, and calculating mean and 2 SE of vegetation variables. I tested for statistical significance of vegetation variables between fledged and failed nests using Mann-Whitney U tests ($\alpha = 0.05$).

RESULTS

I monitored 43 black-capped vireo nests and 54 white-eyed vireo nests in 2008 and 2009 (Table 2.2). Only 24% of black-capped vireo nests (and 29% of camera-monitored nests) fledged at least one host offspring. White-eyed vireo nests were more successful, with 46% total nests fledging at least one offspring. The percentage of white-eyed vireo depredated nests increased from 2008 to 2009. However, results were not significant (U =285.5, P =0.199). Differences in cowbird parasitism rates between years for both species were also not significant (black-capped vireo, U = 123, P =0.237; white-eyed vireo, U =316.5. P =0.503). Sixteen black-capped vireo nests (37.2%) and 5 white-eyed vireo nests (9.2%) failed from abandonment by the vireo pair. Cowbirds parasitized the majority of abandoned nests for both species. Black-capped vireos abandoned 2 additional un-parasitized nests when the eggs failed to hatch.

I placed cameras on 31 black-capped vireo and 54 white-eyed vireo nests for a total of 1043 camera-days. Although I attempted to place cameras at all located nests, I determined vireos abandoned 7 nests with cameras prior to camera setup. No vireo pairs abandoned nests as a result of camera placement.

Table 2.2. Nest fates of monitored black-capped vireo and white-eyed vireo nests on private properties in Coryell Co. TX in 2008 and 2009.

	Black-capped vireo All nests				Camera-monitored nests							
					Black-capped vireo				White-eyed vireo			
	2008		2009		2008		2009		2008		2009	
	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
Abandoned	40.0	4	36.4	12	37.5	3	39.1	9	10.0	3	8.7	2
Depredated	40.0	4	39.3	13	37.5	3	26.1	6	43.3	13	26.1	6
Fledged	20.0	2	21.2	7	25.0	2	30.4	7	46.7	14	65.2	15
Unknown	0.0	0	3.0	1	0.0	0	4.3	1	3.2	1	0.0	0
Parasitized	20.0	2	45.4	15	25.0	2	43.4	10	30.0	9	21.7	5

I recorded 23 predation events by >7 predator species (Table 2.3). The majority of identified predation events occurred during the nestling stage (n = 17). Brown-headed cowbirds and snake species were the most frequent nest predators recorded, accounting for 74% of all predation events. Additionally, cowbirds only depredated non-parasitized nests. Identified ant species included fire ants at the black-capped vireo ant-depredated nest, and *Monomorium spp.* for the ant-depredated white-eyed vireo nest in 2008.

Table 2.3. Identified predator species observed removing nest contents from black-capped vireo and white-eyed vireo nests in Coryell Co. in 2008 and 2009.

		Species					
		Black-capped Vireo			White-eyed Vireo		
		2008	2009	Total	2008	2009	Total
Predator		*n*	*n*	*n*	*n*	*n*	*n*
Brown-headed Cowbird	*Molothrus ater*	2	1	3	4	2	6
Snake spp.	*Elaphe spp.*	1	2	3	3	2	5
Ant spp.	--	--	1	1	1	1	2
Western Scrub-Jay	*Aphelocoma californica*	--	1	1	--	--	0
Hawk spp.	*Accipiter spp.*	--	--	--	1	--	1
Raccoon	*Procyon lotor*	--	--	--	--	1	1
Fox Squirrel	*Scirus niger*	--	--	--	--	1	1
Totals		3	5	8	9	7	16
Unknown		1	0	1	0	1	1
Predation not recorded		0	2	2	6	1	7

Predator Activity Sampling.— I monitored 21 black-capped vireo and 24 white-eyed vireo nests for predator activity using bait stations and 9 black-capped vireo nests and 12 white-eyed vireo nests for herptofaunal activity (Table 2.4). Six of the black-capped vireo bait stations and 10 white-eyed vireo stations did not detect any species. Two herptofaunal traps in 2008 captured 1 frog (*Unknown spp.*) each. One trap in 2009 captured a western diamondback rattlesnake (*Crotalus atrox*) and another trap captured a western coachwhip (*Masticophis flagellum*). I did not capture any other snake species.

Table 2.4. Total of black-capped vireo and white-eyed vireo camera-monitored nests sampled for predator activity in Coryell County, TX in 2008 & 2009.

	Species			
	Black-capped vireo		White-eyed vireo	
Year	Bait Station	Herptofaunal	Bait Station	Herptofaunal
2008	6	3	14	6
2009	14	6	12	6

Bait stations were active for 397 trap-days in 2008 and 722 trap-days in 2009. I detected 19 total species at the bait stations (Table 2.5).

Cattle (*Bos taurus*) were the most frequently detected species within active black-capped vireo areas, accounting for 29.5% of all activity. Eastern spotted skunks (*Spilogale putorius*) accounted for 25% of predator activity at black-capped vireo nests. However, the majority of these detections occurred at only 2 nests. I detected fire ants on bait stations at 55% (*n*=20) of sampled black-capped vireo nests and 96% (n = 26) of sampled bait stations at white-eyed vireo nests throughout the season. For predator activity, there was no apparent difference between the number of visits by all detected species per trap-day and the fate of the nest (black-capped vireo: $U = 47.0$, $P = 0.913$; white-eyed vireo: $U = 48$, $P = 0.212$) (Fig. 2.1). There was also no significant differences between visits per trap day by potential predator species when I excluded visits by non-predator species (cattle, deer, non-corvid avian species, eastern cottontail [*Sylvilagus floridanus*], and nine-banded armadillo [*Dasypus novemcinctus*]) (black-capped vireo: $U = 39.0$, $P = 0.488$; white-eyed vireo: $U = 69.0$, $P = 0.977$) (Fig. 2.2).

Figure 2.1. Mean number of bait station visits by all detected species per trap-day for failed vs. fledged nests of black-capped vireo and white-eyed vireo in Coryell Co. TX in 2008 and 2009. (Error bars ± 2SE)

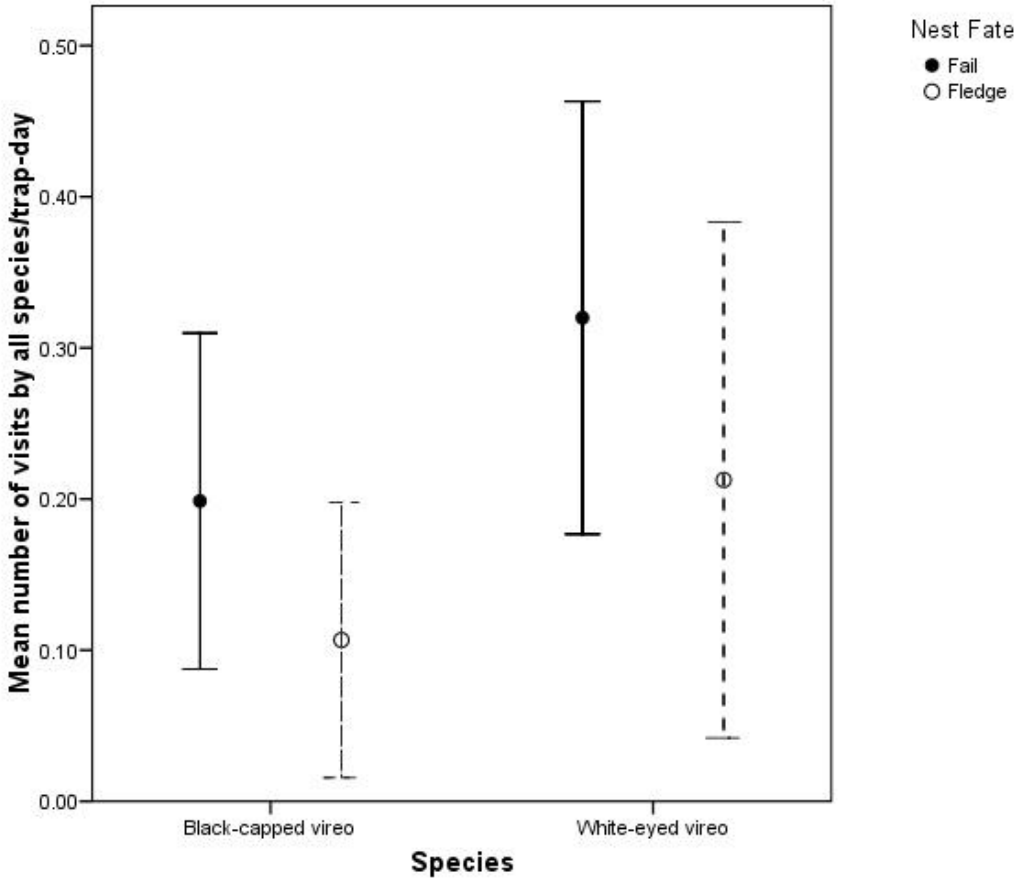

Figure 2.2. Mean number of bait station visits by individual potential predator species per trap-day for failed vs. fledged nests of black-capped vireos and white-eyed vireos in Coryell Co. TX in 2008 and 2009. (Error bars ± 2SE)

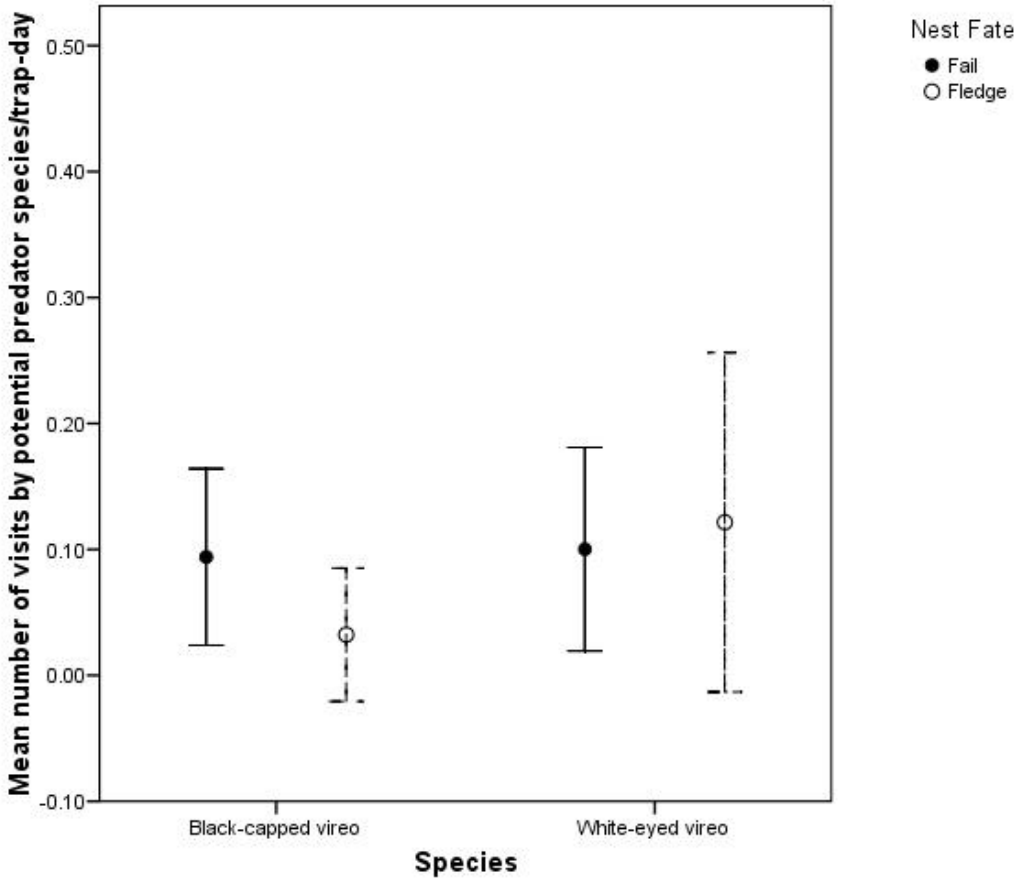

Table 2.5. Number of visits by species identified at predator bait stations and % of total sampled nests where species was detected at active nest locations in Coryell Co. in 2008 and 2009.

		Species											
		Black-capped vireo						White-eyed vireo					
		2008		2009		Total		2008		2009		Total	
Identified species		*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Red-imported fire ants[a]	*Solenopsis invicta*	--	50.0	--	57.1	--	55.0	--	92.9	0	91.7	0	92.3
Carolina Wren	*Thryothorus ludovicianus*	0	0	3	14.3	3	10.0	0	0	0	0	0	0
Northern Cardinal	*Cardinalis cardinalis*	0	0	4	14.3	4	10.0	0	0	1	8.3	0	3.8
Western Scrub-Jay	*Aphelocoma californica*	0	0	1	7.1	1	5.0	0	0	0	0	0	0
Wild Turkey	*Meleagris gallopavo*	0	0	0	0	0	0	1	7.1	2	8.3	3	7.7
Nine-banded Armadillo	*Dasypus novemcinctus*	0	0	0	0	0	0	1	7.1	2	16.7	3	11.5
Eastern Cottontail	*Sylvilagus floridanus*	1	16.7	2	14.3	3	15.0	1	7.1	1	8.3	2	7.7
Cattle	*Bos taurus*	12	50.0	9	21.4	21	30.0	6	21.40	9	8.3	15	15.4
White-tailed Deer	*Odocoileus virginianus*	7	66.7	0	0	7	20.0	29	57.1	30	58.3	59	57.7
Gray Fox	*Urocyon cinereoargenteus*	0	0	2	7.1	2	5.0	0	0	0	0	0	0
Eastern Spotted Skunk	*Spilogale putorius*	0	0	18	21.4	18	15.0	0	0	0	0	0	0
Mouse	--	0	0	3	14.3	3	10.0	6	7.1	22	33.3	28	19.2
Opossum	*Didelphis virginiana*	0	0	2	14.3	2	10.0	0	0	6	33.3	6	15.4
Feral Hog	*Sus Scrofa*	0	0	0	0	0	0	2	7.1	13	8.3	15	7.7
Raccoon	*Procyon lotor*	1	16.7	1	7.1	2	10.0	9	21.4	13	41.7	22	30.8
Eastern Fox Squirrel	*Sciurus niger*	0	0	4	14.3	4	10.0	3	14.3	7	33.3	10	23.1
Coyote	*Canis latrans*	0	0	0	0	0	0	2	7.1	0	0	2	3.8
Lizard spp.	--	0	0	0	0	0	0	0	0	1	8.3	1	3.8
Snake spp.	--	0	0	0	0	0	0	1	7.1	0	0	1	3.8
Totals		21	--	49	--	70	--	61	--	107	--	167	--

[a]Red-imported fire ant detections were only analyzed as presence/absence for each nest location

Vegetation Sampling.— I collected vegetation data from 43 black-capped vireo nests and 54 white-eyed vireo nests (Table 2.6, Table 2.7). Mean nest height differed between black-capped vireo and white-eyed vireo nests ($U = 762.5$, $P = 0.005$). Nest substrate height for black-capped vireo was 1.3x lower than white-eyed vireo ($U = 859$, $P = 0.038$). Distance to habitat edge was also significantly larger for the white-eyed vireo ($U = 714$, $P = 0.002$), averaging nearly 2.25x further (black-capped vireo: $\bar{x} = 5.8 \pm 9.8$m; white-eyed vireo: $\bar{x} = 12.9 \pm 9.8$m). Among species, mean nest height (black-capped vireo: $U = 154.5$, $P = 0.766$; white-eyed vireo: $U = 282$, $P = 0.256$), vegetation height (black-capped vireo: $U = 110.5$, $P = 0.118$; white-eyed vireo: $U = 339$, $P = 0.256$), distance to habitat edge (black-capped vireo: $U = 146$, $P = 0.600$; white-eyed vireo: $U = 230.5$, $P = 0.054$), or average % concealment for 0-2m (black-capped vireo: $U = 152.5$, $P = 0.724$; white-eyed vireo: $U = 245$, $P = 0.095$) did not vary between years. For camera nests, there was no significant relationship between nest fate (fledge vs. fail) and concealment at the nest (black-capped vireo: $U = 91.0$, $P = 0.749$; white-eyed vireo: $U = 339.5$, $P = 0.838$) or distance to edge (black-capped vireo: $U = 79.0$, $P = 0.403$; white-eyed vireo: $U = 330$, $P = 0.882$).

Ant spp. only depredated 1 black-capped vireo nest and 2 white-eyed vireo nests, but in all cases nest height was 20.6% (black-capped vireo: $\bar{x} = 1.0$ m) and 31.1% (white-eyed vireo: $\bar{x} = 1.05$) respectively lower than mean nest height. For both species, distance to edge was greater than mean distance (Table 2.6).

Nest height for snake depredated nests was below mean nest height for black-capped vireo but higher for white-eyed vireo. This difference was only significant for

Table 2.6. Total nests, means, and SD for all monitored black-capped vireo nests and nests by identified predator species for mean nest height, nest substrate height, and overstory vegetation height, distance to nearest habitat edge, and average percent concealment at the nest with a coverboard from 0 – 2m and from 1-1.5m (average nest height) in Coryell, Co. TX in 2008 and 2009.

	Black-capped vireo																			
	Nest Height				Substrate Height				Distance to Edge				% Concealment (0-2m)				% Concealment (1-1.5m)			
Predator Types	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ
None (All nests)	43	1.26	0.43	--	43	3.22	1.70	--	43	6.76	6.78	--	43	63.0	24.23	--	43	58.5	19.66	--
Ant spp.	1	1.00	--	-20.6	1	2.30		-28.6	1	8.00	--	18.3	1	72.8	--	15.6	1	63.0	--	7.7
Brown-headed cowbirds	3	1.17	0.21	-7.4	3	3.7	1.19	13.8	3	3.87	3.61	-42.8	3	70.95	6.25	12.7	3	67.2	6.37	14.8
Avian Predators (other)	1	1.30		3.2	1	5.5		70.8	1	5.30		-21.6	1	45.3		-28.1	1	40.5	--	-30.8
Mammals	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--
Snakes	3	0.76	0.17	-39.9	3	1.97	0.35	-38.9	3	1.2	0.35	-82.2	3	75.13	10.93	19.3	3	75.8	12.37	29.5

Table 2.7. Total nests, means, and SD for all monitored white-eyed vireo nests and nests by identified predator species for mean nest height, nest substrate height, and overstory vegetation height, distance to nearest habitat edge, and average percent concealment at the nest with a coverboard from 0 – 2m and from 1-1.5m (average nest height) in Coryell, Co. TX in 2008 and 2009.

	White-eyed vireo																			
	Nest Height				Substrate Height				Distance to Edge				% Concealment (0-2m)				% Concealment (1-1.5m)			
Predator Types	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ
None (All nests)	53	1.52	0.41	--	53	4.28	2.64	--	52	12.9	9.8	--	53	59.6	15.87	--	53	54.4	18.80	--
Ant spp.	2	1.05	0.07	-31.1	2	2.65	0.21	-38.13	2	13.2	16.7	2.1	2	62	14.85	3.25	2	60.6	22.451	11.46
Brown-headed cowbirds	6	1.3	0.42	-14.7	6	2.52	1.05	-41.24	6	13.3	12.8	2.87	6	61.7	20.34	2.75	6	60.5	23.952	11.15
Avian Predators (other)	1	2	--	31	1	3.5	--	-18.28	1	23	--	77.90	1	40.69	--	-32.2	1	40.8	--	-25.08
Mammals	2	1.3	--	-14.67	2	3.5	--	-18.28	2	2.3	--	-82.2	2	68.25	--	13.66	2	65	--	19.50
Snakes	5	1.59	0.69	4.36	5	4.64	3.17	8.33	5	8.02	10.0	-38	5	65.98	21.32	9.87	5	63.2	24.373	16.19

black-capped vireo ($U = 15.0$, $P = 0.031$; white-eyed vireo: $U = 104.5$, $P = 0.636$). For both species, distance to edge was less than mean distance and again only significantly different for black-capped vireo ($U = 12.0$, $P = 0.022$; white-eyed vireo: $U = 75.5$, $P = 0.186$). Nest concealment did not differ significantly between snake predated nests and all other nests for either black-capped vireo (Concealment 0-2m: $U = 39.0$, $P = 0.317$; Concealment 1-1.5m: $U = 24.0$, $P = 0.086$) or white-eyed vireo (Concealment 0-2m: $U = 92.0$, $P = 0.394$; Concealment 1-1.5m: $U = 82.5$, $P = 0.254$).

Nest height for brown-headed cowbird depredated nests was also below mean nest height for both vireo species. For black-capped vireo, distance to edge for cowbird-predated nests was less than mean distance, for white-eyed vireo, the distance was greater than mean. Neither of these differences was significant for either nest height (black-capped vireo: $U = 56.5$, $P = 0.875$; white-eyed vireo: $U = 86.0$, $P = 0.128$) or distance to edge (black-capped vireo: $U = 47.0$, $P = 0.571$; white-eyed vireo: $U = 128.5$, $P = 0.791$). Additionally, there were no significant differences in nest concealment for cowbird depredated nests and all other nests for either black-capped vireo (Concealment 0-2m: $U = 51.0$, $P = 0.702$; Concealment 1-1.5m: $U = 36.0$, $P = 0.277$) or white-eyed vireo (Concealment 0-2m: $U = 125.0$, $P = 0.671$; Concealment 1-1.5m: $U = 116.0$, $P = 0.501$).

When all nests affected by cowbirds through both parasitism and predation were analyzed, nest height for cowbird-affected nests became higher for black-capped vireo and higher for white-eyed vireo (but still below mean height). However, there were no significant differences between nests for nest height (black-capped vireo: $U = 184.5$,

$P = 0.266$; white-eyed vireo: $U = 274.0$, $P = 0.361$), distance to edge (black-capped vireo: $U = 220.0$, $P = 0.808$; white-eyed vireo: $U = 308.5$, $P = 0.923$) or nest concealment for black-capped vireo (Concealment 0-2m: $U = 211.5$, $P = 0.652$; Concealment 1-1.5m: $U = 200.0$, $P = 0.465$) or white-eyed vireo (Concealment 0-2m: $U = 287.5$, $P = 0.510$; Concealment 1-1.5m:$U = 293.0$, $P = 0.578$).

There was only 1 other avian predator for each species. At a black-capped vireo nest, a western scrub-jay (*Aphelocoma californica*) removed 3 host nestlings and 1 cowbird egg. At a white-eyed vireo nest, an unidentified hawk attempted to capture an adult white-eyed vireo incubating a nest. The white-eyed vireo escaped, but the hawk landing on the branch flung the eggs out of the nest, causing the nest to fail. The black-capped vireo nest was closer to the edge than mean nearest distance, while % concealment was ~28% lower than mean ($\bar{x} = 45.3\%$). The avian-predated white-eyed vireo nest was 78% further from the edge than mean distance. However, % concealment ($\bar{x} = 40.7\%$) was 32% lower than mean concealment.

There were 2 recorded predations by a mammal over the 2 years. A fox squirrel (*Scirus niger)* removed and consumed at least one 1-day-old white-eyed vireo nestling from a nest. 1.5 days later a raccoon (*Procyon lotor*) removed the same white-eyed vireo nest from the nest branch and presumably consumed the remaining nestlings. The nest height ($\bar{x} = 1.3$ m) was below mean height, while the distance to nearest edge ($\bar{x} = 2.3$m) was 82% less than mean distance.

DISCUSSION

Overall, most results varied between species. As predicted, the frequency of predations

by specific nest predator species varied from previous studies. Nest predators of black-capped vireos on Ft. Hood primarily included snakes and fire ants. I initially predicted that both snake and ant predation levels would increase due to differing land use on private lands. Although my research indicated that snakes are indeed major nest predators for both vireo species, the frequency of other species varied. Snake spp. still predated 38% and 33% of black-capped vireo and white-eyed vireo nests respectively, while, ant species accounted for only 13% of total identified predation events. Even with a number of predations that were not recorded due to equipment malfunctions, it is unlikely that ants were responsible for all of the missing predations.

Additionally, only one ant-predated nest contained fire ants in the subsequent nest check. Nestlings at 1 white-eyed vireo nest were consumed by *Monomorium sp.*, and the ants at the third nest were unidentified. The change in this emphasis from fire ants to other predators probably results from differing land management practices. Black-capped vireo-occupied areas within my study sites were not recently disturbed, which may reduce the potential for fire ant activity at nests. On-going military training and frequent fires on Ft. Hood may create more favorable soil conditions for fire ants than grazing alone. Although fire ants may be prevalent in the study area (Campomizzi et al. 2009), results from my predator sampling only detected fire ants at 55% of sampled black-capped vireo nests.

Initially, I also expected predation by brown-headed cowbirds to increase due to smaller-scale trapping efforts on private lands. My results supported this prediction. However, the frequency of cowbird predation events was unexpected. Stake and

Cavanagh (2001) documented on Ft. Hood only 7 depredations on black-capped vireo nests by cowbirds over a 5 year period (and only 2 nests resulting in complete failure); I documented 9 total events, including 3 events on black-capped vireos, and 6 on white-eyed vireo nests. Sixty-seven percent of cowbird predation events for both species resulted in complete clutch failure. While most of these nest predations occurred during the mid-late nestling stage, one cowbird depredated a white-eyed vireo nest after the female cowbird attacked the incubating white-eyed vireo, removed all the host eggs, and then proceeded to parasitize the nest. Even with ongoing localized cowbird trapping, cowbird dynamics appear to differ significantly from Ft. Hood, only a few kilometers to the south. Differences in trapping intensity may have a substantial effect on resulting predation and parasitism levels.

White-eyed vireo nests more frequently fledged host young, but were also more often targeted by predating cowbirds. This may result from a lower likelihood of abandonment following nest parasitism. It has been hypothesized that cowbirds predate unparasitized nests to encourage the host species to renest, offering the cowbird another opportunity to parasitize. Thus, predating a species more likely to accept the cowbird egg would prove beneficial in that regard; white-eyed vireos are slightly larger than their congener and thus may be perceived as a better host. However, this does not explain why black-capped vireos were more likely to be parasitized than white-eyed vireo. I was not successful in locating later nests for the majority of vireo pairs that were depredated by cowbirds, so the rationale behind this cowbird behavior remains unexplained. Regardless, negative cowbird impacts may be larger than previously suspected.

For my second objective regarding activity of potential predator species within the study area, I expected that nest success would decrease with increased activity near the nest. My results suggest there is no relationship between nest success and the number (or species) active within the given nest territory. However, difficulties with herptofaunal sampling and low probabilities of detection for snakes did reduce the ability to draw definitive conclusions from my results. I frequently recorded snake spp. as nest predators, but rarely captured snakes within the sample units (both snake captures occurred near successful nests). My results indicate that while it is extremely difficult, especially within the study region, to document presence or activity of snake species without actively trapping and monitoring snakes using radio-telemetry, they are not actively moving through the vegetation in a predictable manner.

I did observe incidental recordings of Texas rat snakes within sample units at 2 nests, but both white-eyed vireo nests successfully fledged. Later, a black-capped vireo pair built a nest within the same area, but an unknown predator depredated the nest before a camera unit could be deployed.

The classes of species actively moving within vireo territories differed between the two vireos. I detected cattle near 30% of all sampled black-capped vireo nests and 15.4% of white-eyed vireo nests. Cattle were also the most active species, often spending multiple days within a given study unit grazing. Deer were present at the majority of sample areas for both species in 2008 (and for white-eyed vireo in 2009).

Fire ants (only recorded as presence/absence for each nest location) were the most commonly detected predator species. However, even though white-eyed vireo

nests were nearly twice as likely to have fire ants detected (92.3%) than black-capped vireo nests (55%), both species were largely unaffected by ant predations.

My results indicated that there was no significant difference between predator activity and the fate of the nest. This is to be expected, since only 4 of the total detected species were observed depredating a vireo nest. Additionally, even though multiple species moved with regularity within the vicinity of the active nest, this extra behavior did not contribute towards an increased predation risk. While neither deer nor cattle directly caused nest failures; I recorded cattle passing within 2m of an active black-capped vireo nest on multiple occasions, and both species have the potential to negatively impact vireos by consuming or trampling potential nest habitat while grazing.

Micro-scale vegetation data indicated a difference of habitat preference between the two vireo species. White-eyed vireos frequently constructed higher nests and favored vegetation in a later seral stage than the black-capped vireo. However, each species did not use their territories mutually exclusive of the other, as I often observed them interacting together. For example, white-eyed vireo fledglings begged for food from adult male black-capped vireos on multiple occasions (personal observations). White-eyed vireo preference for more overgrown habitat may allow the 2 species to coexist with limited competition. However, it may play an additional factor determining nest success. Black-capped vireo preference for habitat edges may make them more vulnerable to predation by edge-specialist species such as snakes and ant species.

For my third objective, I predicted that based on vegetation characteristics, predation events by fire ants (and other ant spp.) would decrease with increasing nest

height, and not vary with any over vegetation variable such as concealment, since distance from ground would be the major factor limiting ant foraging efforts. I also predicted predation events by all other species would increase with decreasing vegetation concealment at the nest and distance to edge of habitat patch. I expected mammalian predation events to decrease with increasing distance to edge, while avian predation events would increase. Snake predation events would be unaffected by nest height and were expected to increase with proximity to edge.

Overall, my results showed no distinct relationship between nest fate (fledge vs. failed) and vegetation characteristics. Given the variation in habitat and the variety of potential predator species, this is to be expected. However, there was an apparent relationship between vegetation and classes of predators; this supports my general hypothesis that the importance of vegetation characteristics would vary between predator species.

For ant species, I predicted that nest height and distance would be lower than the mean values. Although I only had 3 total events, ant nests were lower than mean nest height but further from the habitat edge than the mean distance, however the distance to edge was larger than mean. This may indicate that while lower nests are more likely to be exposed to foraging ants, ant populations appear to be distributed throughout the habitat and do not necessarily show a preference for disturbed edge habitat. This corresponds with my predator sampling indicating that ants were active near 92% of white-eyed vireo nests.

Sperry et al. (2009) determined that snakes at Ft. Hood were more active along

these black-capped vireo habitat edges, and thus negatively affected black-capped vireo success. My results support this as well, since snake species appear to be preferentially depredating nests closer to the edge for both vireo species. Black-capped vireos, which nest closer to the edge, showed a larger potential relationship in this regard since snake-depredated nests showed an 80% decrease from mean distance to edge. Fragmentation on private properties resulting from roads, fence lines, pastures, juniper clearing, and other factors may reduce the size of habitat patches, forcing vireos to nest closer to these edges, which may increase the risk of being depredated by snakes.

Nest height for snake-depredated nests of both species also showed a marked decrease from mean values. This may indicate that foraging snakes observed nests during systematic movements through the habitat, and then returned later to depredate the nest contents. Although I did observe incidental sightings of rat snakes during the day both during site visits and through video footage, snakes only depredated at night. Darkness may provide additional cover for the snake, reducing adult vireo disturbance and providing security from predators that consume snakes.

My results regarding nest height, distance to edge, and vegetation concealment for other predator classes (avian, mammals) differed from my predicted results (and between vireo species); however, these differences likely reflect habitat and foraging preferences by the individual predator species. The black-capped vireo nest depredated by the western scrub-jay was close to the habitat edge. Western scrub-jays are known to prefer scrub and edge habitats, and thus would likely predate a nest within this area. The hawk observed depredating the white-eyed vireo nest was probably a forest specialist

such as an accipiter species, and thus would be expected to depredate interior habitat nests. I predicted that mammal-predated nests would be closer to ground level than mean height, since the predation would be ground based, and even though there was only 1 event observed, this predation did fit my previous prediction. The absence of other mammalian predators may be due to land management practices within the region. Many of the private properties contain 3-m high fence lines to contain wildlife such as deer within property boundaries. This fencing may impede movements of medium and large-sized mammalian predators, and thus change dynamics of the system. Additionally, some landowners may engage in predator culling by physically removing meso-carnivores perceived to be detrimental to livestock, such as coyotes (*Canis latrans*). The absence of these predators may increase the abundance of other predator species, including those who may be primary predators of nesting songbirds (Crooks and Soulé 1999, Ritchie and Johnson 2009).

CHAPTER III

ANALYSIS OF THE BLACK-CAPPED VIREO NEST PREDATOR ASSEMBLAGE

Predation is the leading cause of nest failure in songbirds (Martin 1993, Grzybowski 1995, Schmidt and Whelan 1999). However, only a few studies directly address nest predators or the relationships between predator assemblages (Sovada et al. 2000, Smith 2004), or predators and habitat type (Kuehl and Clark 2002, Thompson and Burhans 2004, Stake et al. 2005, Marzluff et al. 2007, Thompson 2007). Predator assemblages may also be altered by different land use practices or fragmentation of the landscape (Thompson 2007, Sperry et al. 2009), which in turn may have an effect on the composition of the predator assemblage (Chalfoun et al. 2002). Since spatial and temporal patterns of predators may drive reproductive success for avian species (Sperry et al. 2008, Benson et al 2010), understanding the effects of habitat characteristics on the avian nest predator assemblage is an important step for avian conservation.

Until recently, studies focusing on predators were also limited due to technology. Predator identification was based solely on incidental sightings or inferences from remaining nest contents (Martin 1993, Grzybowski 1995, Schmidt and Whelan 1999), which can lead to inaccurate identifications (Williams and Wood 2002). New monitoring methods utilizing video cameras for continuous surveillance (Delaney et al. 1998, Stake and Cimprich 2003, Thompson and Burhans 2003, Stake et al. 2004, Pierce and Pobprasert 2007) allow for enhanced predator identification.

Use of more accurate identification methods has shown the predator assemblage, much like the level of edge effects, depends on region and spatial characteristics of the habitat. Small and medium sized mammals are dominant predators in fragmented forests (Stake and Cimprich 2003, Thompson and Burhans 2003, Schaefer 2004, King and DeGraaf 2006), whereas snakes are dominant predators in southern shrub habitats (Stake and Cimprich 2003). An introduced predator in the southern U.S., the red imported fire ant (Solenopsis *invicta,* hereafter "fire ant") is known to swarm and kill hatching birds and nestlings of multiple avian species (Kopachena et al. 2000, Allen et al. 2001, Stake and Cimprich 2003, Allen et al. 2004, Campomizzi et al. 2009). In addition, many songbird species have reduced nest success resulting from parasitism and nest predation by the brown-headed cowbird (*Molothrus ater*) (Stake and Cimprich 2003). Cowbirds are a parasitic-generalist species that remove host eggs (and occasionally nestlings) and lay their own eggs in the host nest (Elliott 1999). Understanding these dominant and co-existing predators and their relationships with the surrounding habitat and prey species is essential component for endangered species management in Texas, where multiple species (snakes, corvids, cowbirds, and fire ants) have been identified as major nest predators for endangered songbirds like the black–capped vireo (*Vireo atricapilla*).

The black–capped vireo (hereafter "vireo"), is a federally endangered songbird (Ratzlaff 1987) whose numbers have been declining due to habitat loss, habitat fragmentation, and parasitism by brown-headed cowbirds (Grzybowski 1995). The breeding range for the vireo extends from localized areas in western Oklahoma through central Texas and south to Coahuila, Mexico, although the historical range stretched

north into south-central Kansas (Grzybowski et al. 1994, Grzybowski 1995). Typical vireo breeding habitat is clumps of shrubby deciduous vegetation of irregular heights; these clumps cover 35–55% of the habitat and vegetation cover usually extends to ground level (Grzybowski et al. 1994, Bailey and Thompson 2007).

Predator research regarding vireos is limited. Stake and Cimprich (2003) used a video monitoring system on Ft. Hood in east-central Texas to examine nest predators at 142 vireo nests. Texas rat snakes (*Elaphe obsoleta lindheimeri*) and red imported fire ants accounted for 38% and 31%, respectively, of predation events on vireo nests. While recent studies have focused on temporal and spatial habitat use of Texas rat snakes on Ft. Hood (Sperry et al. 2008), limited studies have addressed the temporal and spatial activity patterns of other vireo predators. Fire ants may adversely affect nest success of breeding songbirds within the study region (Campomizzi et al. 2009) and ant peak foraging activity is strongly tied to soil temperatures around ~29 degrees C (Vogt et al. 2003), which coincides with the vireo breeding season from April through July in east-central Texas.

Other than nest video collected at Ft. Hood or incidental observations at nests (Graber 1961, Grzybowski 1995) no information exists for vireo nest predation events or nest predators (snakes, avian species, mammals, or ant species) in any other region of the species' range. Vireo habitat covers a wide variety of ecotones, ranging from the Edwards Plateau dominated by regular rainfall and multiple *Quercus spp.* providing successional habitat to vegetation on the western boundary where xeric shrub habitat dominates the landscape. Given this change in environmental conditions across the

range, it is reasonable to expect that the predator assemblage (and thus major limiting factors) may differ depending on location and vegetation. Understanding and identifying the vireo predator assemblage range-wide offers the opportunity to ensure that species management is effective wherever applied.

It is also important to understand the effects of brown-headed cowbirds on vireo nest predator activity and nest predation levels because cowbirds can cause nest failure through either nest parasitism or predation. Although some small-bodied songbirds recognize and reject cowbird eggs, vireos accept cowbird eggs laid in their nest, and the presence of a cowbird egg means failure of the host clutch. Previous studies have shown that cowbirds will remove host eggs and host nestlings from vireo nests (Stake and Cavanagh 2001, Stake and Cimprich 2003).

To explain the relationship between nest parasitism and nest predation, it has been theorized that cowbirds either directly (the cowbird predation hypothesis) or indirectly (cowbird facilitation hypothesis) cause nest failure by predation in host species (Duncan and Jenkins 1998, Mullin and Cooper 1998). The predation hypothesis argues that female cowbirds depredate host nests located late in the nesting cycle to induce re-nesting by host species (and thus create future parasitism opportunities). It predicts that un-parasitized nests will fail more frequently than parasitized nests due to female cowbirds destroying nests. However, if female ranges overlap, the cowbird predation hypothesis predicts nest success of parasitized nests to be less than un-parasitized nests since there is a greater potential for different cowbirds to discover the same nest. The facilitation hypothesis predicts that the parasitism-predation relationship is due not to

direct predation events by cowbirds, but rather that parasitism events attract alternative predator species to the nest. Previous data collected within the vireo range indicates that the proportion of depredated nests is higher if the nest has been parasitized (unpublished data). If this pattern holds true, the use of video surveillance at nests would determine if: a) the higher failure rates of parasitized nests are due to predation by female cowbird with overlapping territories as predicted by the cowbird predation hypothesis and b) if the presence of a cowbird predation event increases the likelihood of future nests at that site to be parasitized.

Despite the success of cowbird trapping at reducing nest parasitism rates, trapping for cowbirds may have unintended consequences if individual cowbirds are responsible for nest predation. Cowbirds appear to predate only nests that contain no cowbird eggs or offspring (Stake and Cavanagh 2001). If trapping reduces the instances of parasitism in vireo nests, a possible increase in the number of cowbird predation events may occur since fewer nests would have cowbird-related contents. Although addling of cowbird eggs in parasitized nests is possible to prevent the cowbird from hatching, there is no simple control method to prevent adult cowbirds from predating nests.

My objectives for this study were to: 1) identify nest predators of vireos, 2) examine the relationships between vegetation characteristics and the identified nest predator species, and 3) examine the relationship between cowbird parasitism and predation at the nest.

For my first objective, I predicted that frequency of predations by specific nest predator species would vary from previously collected data due to different ecotones and management strategies. I expected higher levels of snake and ant predations due to grazing and brush management on study sites creating disturbed habitat favored by these species. I also expected incidents of predation by brown-headed cowbirds to increase due to the localized small-scale trapping efforts on other public and private lands.

Table 3.1. Predicted frequency of predation events at black-capped vireo nests that are expected to increase (↑) or decrease (↓) with increasing nest height (m), increasing distance from nest to habitat edge (m) and increasing mean % concealment at the nest.

	Frequency of predation events		
	↑ Nest Height (m)	↑ Distance to edge (m)	↑ % Concealment (0-2m)
Ant Spp.	↓	↓	no difference
Avian Spp.	↑	↑	↓
Brown-headed cowbirds	↑	↑	↓
Mammals	↓	↓	↓
Snakes	↓	↓	↓

Based on vegetation characteristics (Table 3.1**),** I predicted that predation events by fire ants (and other ant spp.) would decrease with increasing nest height, and not vary with any over vegetation variable such as concealment, since distance from ground would be the primary factor limiting ant foraging. I predicted predation events by all other species would increase with decreasing vegetation concealment at the nest. For distance to edge of habitat patch, I expected mammalian predation events to decrease, while avian predation events would increase. Snake predation events would be

unaffected by nest height and were expected to increase with proximity to edge (Sperry et al. 2009).

For my third objective, I sought to examine the relationships between predation events and cowbird parasitism of the nest at each study area. I predicted that nests not parasitized by cowbirds would suffer a higher proportion of depredation events than unparasitized nests due to cowbird attempts to induce nest failure. I also predicted that the presence of a cowbird predation event would increase the likelihood of future nests at that site to be parasitized. This should hold true unless future parasitism of a given nest is independent of cowbird predation history in an area and thus cowbirds are predating nests for reasons other than to create parasitism opportunities as previously predicted by the cowbird predation hypothesis (Table 3.2).

Table 3.2. Predicted frequency of predation and future parasitism events that are expected to increase (↑) or decrease (↓) based on whether the nest has been parasitized or depredated by cowbirds.

	Frequency of predation and parasitism	
	Predation events	Future parasitism events
Non-parasitized nests	↑	n/a
Parasitized nests	↓	n/a
Cowbird-predated nests	n/a	↑

STUDY AREAS

In 2008 and 2009, I monitored vireo nests at 3 separate study locations in central and southwest Texas. I monitored nests on privately-owned properties within Coryell County in east-central Texas, on public land at Kerr Wildlife Management Area and

privately-owned properties in Kerr County, Texas, and on public land Devils River State Natural Area in Val Verde County, TX (2009 only).

Properties in Coryell County (Coryell Co.) selected for this study were part of a larger research initiative- the Leon River Restoration Project (LRRP), and later the Recovery Credit System (RCS). LRRP and RCS were designed to document golden-cheeked warbler (*Dendroica chrysosparia)* and black-capped vireo occupancy, distribution, and abundance monitoring on private properties in the region. Research has been ongoing since 2003 (Leon River Restoration Project 2005, Institute of Renewable Natural Resources 2007, Butcher et al. 2010). The 11 properties selected contained active vireo territories detected during property surveys. The topography consists of rocky limestone hillsides and mesas ranging in elevation from 200–500 m and primary land uses in the area are ranching, hunting, and farming. Adjoining the region to the south is Ft Hood, where the largest known population of vireo exists. Ft. Hood has been monitoring vireos since 1987.

I also collected data from Kerr Wildlife Management Area (Kerr) and 5 private properties bordering Kerr in Kerr County, TX. Private properties were selected based on permission from landowners. Publically owned and managed by the Texas Parks and Wildlife Department, Kerr is located at the headwaters of the North Fork of the Guadalupe River and consists of 2628 ha of limestone landscape features typical of the Edward's Plateau ecoregion. Primary land uses are for ecological and wildlife-based research and public access for hunting and wildlife viewing. Various stages of land and wildlife management, including localized cowbird trapping, have been ongoing since the

property was acquired from private sources in 1950 (Texas Parks and Wildlife Department 2008b). Systematic cowbird trapping has reduced local parasitism rates to ~33% (T. L. Pope, personal communication).

In 2009 I also collected data at Devils River State Natural Area (Devils River) in Val Verde County, TX. Devils River State Natural Area was acquired as public land in May 1988, and is also managed by the Texas Parks and Wildlife Department. The area covers approximately 8100ha and includes features of multiple ecoregions including Edwards Plateau on the east, south Texas brush habitat in the southern section of the park, and Trans-Pecos habitat to the west. Vegetation includes stands of live oak and pecan trees near the Devils River and xeric grassland on the surrounding ridges and slopes, along with multiple springs that provide the majority of water to the river. Primary land uses in the area are wildlife viewing and human recreation (Texas Parks and Wildlife Department 2008a). There is no active cowbird trapping at Devils River.

METHODS

I located active vireo territories to use as study sites for nest monitoring through ongoing point count surveys for LRRP and RCS, as well as historical territory locations. Potential sample units selected for surveying included all private lands active in either LRRP or RCS programs within Coryell County and public lands within Kerr WMA and Devil's River SNA and that contained historic or current vireo territories.

Surveyed locations included both currently/historically occupied vireo habitat, as well as unoccupied habitat patches that met criteria for vireo habitat (Graber 1961, Grzybowski 1995). I visited potential study sites at least once every 10 days in order to

maximize the potential of detecting resident vireos. (Ralph et al. 1991, Grzybowski 1995)

Nest Searching and Video Monitoring.—I located nests for vireo in each sample unit by using behavioral observations of adult birds and systematic search techniques (Martin and Geupel 1993). I monitored active nests at all locations using visual checks every 2-7 days. If a nest was parasitized and contained a cowbird egg, I addled the egg to prevent hatching and replaced it in the nest.

For additional monitoring, I utilized a video camera system to accurately identify predators and nest fate. The system consisted of a weatherproof bullet camera with a 1/3", 3.6mm lens and infrared lighting (Rainbow, Costa Mesa, CA) to record night events placed near enough to the nest to capture all activity, but not disturb the birds (approximately 1-2 m). A 15-m cable connected the camera unit to a digital video recorder ([DVR], Detection Dynamics, Austin, TX) and a 12v 26ah battery (Batteries Plus, Hartland, WI). In 2008, I used 4GB SD memory cards and a time-lapsed recording of 5fps to maximize data storage on the DVR. I checked the camera system every 2–3 days to replace data cards and batteries as needed and left the camera in place until the nest fledged or failed. For 2009, I upgraded the data storage to 8 GB SD cards and supplemented battery power with 20– watt solar panels (Suntech, San Francisco, CA) to reduce the number of visits to the active territories. I had 20 camera units at Coryell Co., 10 units available for use at Kerr, and 15 camera units at Devils River.

Selection criteria for camera nests varied by study location. In Coryell Co., where vireo numbers were limited, I attempted to place cameras on every active vireo

nest. At Kerr and Devils River I selected nests based on availability of camera units, distribution of nests through available vireo habitat type (shrubland, juniper woodland and deciduous woodland at Kerr; low flats, canyon slopes, and riparian areas at Devils River), and nest stage. If multiple nests were available, I preferentially chose nests earlier in the nesting cycle (i.e. day 2 of incubation vs. day 12).

Vegetation Sampling.—I collected vegetation measurements at each nest location, and data collection only occurred after nests were no longer active. Vegetation measurements included vegetation maximum height at nest, distance and direction to nearest edges, slope, nest substrate, nest height, and percentage of visual obstruction by vegetation 1m from nest in the cardinal directions, above, and below nest. I measured additional concealment data using a profile board at 7 m from nest location from each of the cardinal directions (Guthery et al. 1981).

I conducted statistical analysis using SPSS 15.0 (SPSS Inc, Chicago, IL). I used ANOVA ($\alpha = 0.05$) to compare differences between nest success, parasitism, predation, predator species, and vegetation characteristics between study locations. I analyzed vegetation data by examining box plots, scatter plots, histograms, and calculating mean and 2 SE of vegetation variables. I used Mann-Whitney U tests ($\alpha = 0.05$) to test for statistical significance of vegetation variables between fledged and failed nests and differences between mean vegetation variables and vegetation at predator-specific nests. I also used Mann-Whitney U tests to examine potential differences between parasitized vs. unparasitized nests.

RESULTS

I monitored 115 vireo nests with cameras in 2008 and 2009, for 1323 camera-days (Table 3.3). In Coryell County, only 29% of vireo nests fledged ≥ 1 host offspring. Kerr fledged 37% host nests, while Devils River only fledged 28%. Abandonment rates varied from 18.6% to nearly 40% between sites. However, almost all nest abandonment (92%) occurred after parasitism by a brown-headed cowbird. Two vireo nests in Coryell Co. were un-parasitized but later abandoned when the eggs failed to hatch during incubation. Vireos abandoned 1 additional nest at Kerr WMA after a grey fox (*Urocyon cinereoargenteus*) lay down under the active nest for 4 hours. The fox left the nest undisturbed, but the adults did not return. Vireos abandoned 14 camera nests prior to camera setup, and thus no video footage was available for analysis. No nests were directly abandoned because of camera placement.

Table 3.3. Nest fates and overall parasitism rates for camera-monitored black-capped vireo nests at Coryell County, Kerr WMA, and Devils River SNA, TX in 2008 and 2009.

	Location									
	Coryell County				Kerr				Devils River	
	2008		2009		2008		2009		2009	
	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
Abandoned	37.5	3	39.1	7	10.0	2	23.8	5	18.6	8
Depredated	20.0	4	30.4	7	40.0	8	47.6	10	51.1	22
Fledged	37.5	3	26.1	6	45.0	9	28.6	6	27.9	12
Unknown	0.0	0	4.3	1	5.0	1	0.0	0	2.3	1
Parasitized	25.0	2	43.4	10	10.0	2	23.8	5	37.2	16

Nest Searching and Video Monitoring.— In 2008 and 2009 I recorded 37 predation events by >10 identified predator species (Table 3.4). I defined a predation event as a nest visit by a non-host species resulting in partial or total removal or failure of nest contents. Avian species (59.4%;cowbirds comprised 29% of all predations) and snake species (35.4%) were the most frequently identified nest predator species at all study locations. Additionally, nearly all cowbird predation events resulted in removal of the entire clutch and failure of the nest. At one vireo nest the female cowbird removed two host nestlings, attacked one in the nest, and accidently knocked 1 over the rim of the nest. One nestling was alive on the ground and being fed by the adults when located 2 days later. Additionally, the injured nestling in the nest survived 1.5 days before being consumed by fire ants.

Regionally, other major predator species varied by location. In Coryell Co., snake spp. and cowbirds were responsible for 75% of all recorded predation events. At Kerr WMA, avian species accounted for the majority of nest predation events. One mammal species (*Canis latrans*) was observed predating a nest. This event occurred when a snake was at the nest actively consuming four nestlings. At Devils River SNA, avian species accounted for 46.2% of all predation events, and mammals were responsible for 27%.

Vegetation Sampling.— I collected vegetation data from all camera nests. Neither mean nest height ($F = 0.037$, $P = 0.963$) or mean nest substrate height ($F = 0.989$, $P = 0.375$) differed significantly between locations. However, both nearest distance to edge ($F = 21.02$, $P < 0.001$), mean distance to edge from all 4 cardinal directions ($F = 21.02$,

$P < 0.001$) and concealment from 0-2 m ($F = 24.13$, $P < 0.001$), as well as % concealment from 1-1.5 m ($F = 16.69$, $P < 0.001$) were distinct between locations. Distance to nearest edge was greatest at Coryell Co (6.43 ± 6.45 m), while only 1.50 ± 0.86 m and 1.40 ± 2.5 m at Kerr WMA and Devils River, respectively. Mean distance to edge from all 4 cardinal directions at Coryell Co. was ~250% greater than the other 2 locations (Table 3.5).

Both mean vegetation concealment from 0-2m at the nest location and mean concealment at approximate nest height increased ~10% from Coryell Co. to Kerr, and ~10 from Kerr to Devils River. At locations sampled in both 2008 and 2009, mean nest height, vegetation height, distance to habitat edge, or mean concealment did not significantly vary between years. However, mean % concealment at approximate nest height (1-1.5m) did differ between years at Kerr WMA ($U = 104.5$, $P = 0.004$).

Vegetation measurements varied between identified predator species (Table 3.5). Ant spp. only depredated 5 total nests, but in all cases nest height was below mean nest height (Coryell Co.: -18% difference from mean; Kerr: -2.7%; Devils River: -27%). For Coryell Co, distance to edge was 24.5% greater than mean distance ($\bar{x} = 8.0 \pm 0.0$ m), but for the other two locations, distances to edge for ant-predated nests at Kerr WMA and Devils River SNA were 43.2% shorter and 33.1% shorter respectively than mean distance.

For nests depredated by cowbirds, nest height was below mean nest height for both Coryell Co. ($U = 44.5$, $P = 0.91$) and Devils River ($U = 47.5$, $P = 0.57$), while higher at Kerr ($U = 43.5$, $P = 0.52$). Nearest distance to edge was also lower for both

Table 3.4. Recorded nest predator species observed removing nest contents at black-capped vireo nests in Coryell Co, Kerr WMA, and Devils River SNA, TX in 2008 and 2009.

		Study Areas															
		Coryell Co.						Kerr WMA						Devils River SNA			
		2008		2009		Total		2008		2009		Total		2009		Total	
Predator		%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
Snake spp.	*Elaphe spp.*	33	1	40	2	38	3	71	5	11	1	38	6	15	2	15	2
Brown-headed Cowbird	*Molothrus ater*	67	2	20	1	38	3	14	1	22	2	19	3	23	3	23	3
Ant spp.		--	--	20	1	13	1	--	--	22	2	13	2	15	2	15	2
Hawk spp.	*Accipiter spp.*	--	--	--	--	--	--	--	--	11	1	6	1	--	--	--	--
Western Scrub-Jay	*Aphelocoma californica*	--	--	20	1	13	1	14	1	22	2	19	3	8	1	8	1
Coyote	*Canis latrans*	--	--	--	--	--	--	--	--	11	1	6	1	--	--	--	--
Ringtail	*Bassariscus astutus*	--	--	--	--	--	--	--	--	--	--	--	--	8	1	8	1
Greater Roadrunner	*Geococcyx californianus*	--	--	--	--	--	--	--	--	--	--	--	--	15	2	15	2
Gray Fox	*Urocyon cinereoargenteus*	--	--	--	--	--	--	--	--	--	--	--	--	15	2	15	2
Totals		--	3	--	5	--	8	--	7	--	9	--	16	--	13	--	13
Predation not recorded		--	0	--	2	--	2	--	0	--	0	--	0	--	6	--	6
Unknown		--	1	--	0	--	1	--	1	--	0	--	1	--	5	--	5

Table 3.5. Total nests, means, SD, and % difference from mean of all nests for all monitored black-capped vireo nests and nests by identified predator species for mean nest height, nest substrate height, and overstory vegetation height, distance to nearest habitat edge, and mean percent concealment at the nest with a coverboard from 0 – 2m and from 1–1.5m (mean nest height) in Coryell, Co. TX, Kerr WMA, TX, and Devils River SNA, TX in 2008 and 2009.

Coryell Co.

	Nest Height				Substrate Height				Distance to Edge				% Concealment (0-2m)				% Concealment (1-1.5m)			
Predator Types	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ
None (All nests)	34	1.21	0.40	--	43	3.17	1.62	--	43	6.43	6.45	--	43	64.5	17.2	--	43	60.5	17.7	--
Ant spp.	1	1.00	--	-17.4	1	2.30	--	-21.9	1	8.00	--	24.5	1	72.8	--	-1.3	1	63.0	--	-11.7
Brown-headed cowbirds	3	1.17	0.21	-3.6	3	3.67	1.19	24.55	3	3.87	3.61	-39.8	3	70.95	6.25	-3.70	3	67.17	6.37	-5.90
Avian Predators (other)	1	1.30	--	7.4	1	5.50	--	86.83	1	5.30	--	-17.5	1	45.25	--	-38.59	1	40.50	--	-43.26
Mammals	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--
Snakes	3	0.76	0.17	-37.5	3	1.97	0.35	-33.20	3	1.20	0.35	-19.75	3	75.13	10.93	1.96	3	75.75	12.37	6.12

Kerr WMA

	Nest Height				Substrate Height				Distance to Edge				% Concealment (0-2m)				% Concealment (1-1.5m)			
Predator Types	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ
None (All nests)	41	1.23	0.44	--	41	2.94	1.32	--	41	1.50	0.86	--	41	73.7	11.3	--	41	71.4	17.1	--
Ant spp.	2	1.20	0.57	-2.7	2	2.75	0.35	-6.6	2	0.85	1.20	-43.2	2	72.8	--	-1.3	2	63.0	--	-11.7
Brown-headed cowbirds	3	1.33	0.38	8.1	3	2.5	1.1	-13.9	3	2.00	1.13	33.8	3	71.0	6.25	-3.7	3	67.2	6.37	-5.9
Avian Predators (other)	4	1.60	0.81	29.8	4	3.45	0.80	17.2	4	1.65	1.24	10.4	4	74.9	11.8	-38.6	4	71.6	7.8	-43.3
Mammals	1	1.70	--	37.9	1	3.25		10.4	1	1.40	--	-6.4	1	62.80	--	-14.8	1	70.00	--	-1.9
Snakes	6	1.2	0.55	-2.7	6	2.23	1.37	-24.3	6	1.3	0.7	-10.8	6	75.13	10.93	2.0	6	75.8	12.37	6.1

Table 3.5 continued

Devils River SNA

	Nest Height				Substrate Height				Distance to Edge				% Concealment (0-2m)				% Concealment (1-1.5m)			
Predator Types	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ	*N*	$\bar{x}$	SD	%Δ	*n*	$\bar{x}$	SD	%Δ
None (All nests)	43	1.21	0.43	--	43	3.40	1.48	--	43	1.40	2.50	--	43	84.7	9.7	--	43	81.9	13.9	--
Ant spp.	2	0.90	0	-27.0	2	3.40	1.56	15.5	2	1.00	1.27	-33.1	2	87.5	3.3	18.7	2	89.8	4.6	25.7
Brown-headed cowbirds	3	1.03	0.25	-16.2	3	4.8	1.1	61.9	3	0.7	0.46	-53.2	3	90.875	4.49	23.3	3	91.7	10.8	28.4
Avian Predators (other)	3	1.07	0.40	-13.5	3	2.73	0.23	-7.2	3	1.17	0.78	-22.0	3	90.5	1.3	22.8	3	83.2	7.3	16.5
Mammals	3	1.93	0.80	56.8	3	2.90	1.01	-1.5	3	5.43	9.15	263.4	3	84.38	14.85	14.5	3	83.33	11.79	16.7
Snakes	2	0.75	0.07	-39.2	2	2.95	1.06	0.2	2	0.5	0	-66.6	2	86.24	6.71	17.1	2	88.0	0.0	23.3

Coryell Co. ($U = 36.5$, $P = 0.56$), and Devils River ($U = 51$, $P = 0.70$), while higher at Kerr ($U = 40.5$, $P = 0.40$). When all nests affected by cowbirds through both parasitism and predation were analyzed, nest height for cowbird-affected nests became higher than mean height at all locations, including for Coryell Co. ($U = 125.5$, $P = 0.53$), and Devils River ($U = 158$, $P = 0.1$). Nest height decreased slightly at Kerr ($U = 133$, $P = 0.52$), although cowbird-combined was still taller than mean height. For mean distance to edge of cowbird-affected nests, distances in Coryell Co. nearly equaled mean distance ($U = 143.5$, $P = 0.97$), Devils River increased by 58% ($U = 210$, $P = 0.71$), and Kerr was significantly larger than mean nearest distance ($U = 85$, $P = 0.03$).

Nest height for nests depredated by all avian predators combined, including cowbirds, western scrub-jay (*Aphelocoma californica*), hawk spp., and greater roadrunner (*Geococcyx californianus*) nests was above mean nest height for Coryell Co. ($U = 125.5$, $P = 0.53$) and Kerr ($U = 188$, $P = 0.99$), but 13.5% lower for Devils River ($U = 185.5$, $P = 0.28$). Distance to edge at avian-predated or parasitized nests was also less than mean distance for Coryell Co. ($U = 143.5$, $P = 0.985$) and Devils River ($U = 213.5$, $P = 0.69$), but higher for Kerr ($U = 111.5$, $P = 0.023$).

There were no recorded mammal predations in Coryell Co. For both Kerr and Devils River, mammal-predated nest height was above mean nest height (Kerr: $U = 5$, $P = 0.29$; Devils River: $U = 20.5$, $P = 0.058$). Mean distance to edge was lower for Kerr ($U = 17.5$, $P = 0.86$), and substantially higher for Devils River. However, Devils River was not statistically significant ($U = 50.5$, $P = 0.668$), since 1 of the 3 nests was an outlier (16 m vs. 0.1 m and 0.2 m respectively).

Nest height for snake depredated nests was below mean nest height for all locations, and was significantly below mean for Coryell Co. ($U = 8$, $P = 0.013$). Distance to edge at nests with snake depredation was shorter than mean distance for all locations, and significantly below mean for Coryell Co. (Coryell Co., $U = 11$, $P = 0.028$; Kerr WMA, $U = 90$, $P = 0.54$; Devils River SNA, $U = 35$, $P = 0.76$). For cowbird effects, nests not parasitized by cowbirds suffered a higher proportion of depredation events than parasitized nests at all sites (Table 3.6) However, results were only statistically significant at Devils River ($U = 129$, $P = 0.026$).

Table 3.6. Percentage of parasitized or non-parasitized nests that failed due to predation in Coryell County, Kerr WMA, and Devils River SNA, TX in 2008 and 2009

	Location		
	Coryell Co.	Kerr WMA	Devils River SNA
Nest Status	%	%	%
Parasitized	21.4	14.0	31.0
Non-parasitized	38.0	48.0	62.0

Out of the nine cowbird depredated nests, I only had data on later nesting attempts for four pairs. One pair at Kerr was depredated by a cowbird, but was unparasitized (and successful) on their second nesting attempt. At Devils River, after 1 pair was depredated by cowbirds on their first nest attempt, parasitized (and later abandoned) on their second nesting attempt, and was not parasitized on their third nest attempt, which fledged. Another pair at Devils River was also predated by cowbirds on their first nest attempt. Their second nest was unparasitized but later predated in the nestling stage. Nesting attempt three was parasitized but the egg was addled and the nest

was ultimately successful. In Coryell Co., the only documented second nest attempt after cowbird predation was parasitized and the vireo pair later abandoned the nest.

DISCUSSION

Overall, most results varied by location. Both success and parasitism differed markedly between study sites. Nests in Coryell Co. were more likely to be abandoned than at the other two locations. However, depredation rates were 17-21% lower than at either Kerr or Devils River. Although 2008 was a more successful year, with 37.5% (Coryell) and 45% (Kerr) of nests fledging at least 1 host young, success rates were similar across all locations each year. Thus, it appears that while vireo success remains limited across the Texas range, mechanisms limiting this success vary depending on location.

Parasitism rates were highest in Coryell Co., which may be driving vireos in that region to preferentially abandon parasitized nests in order to attempt a renest. Abandonment rates suggest that vireos at other locations are also abandoning parasitized nests more frequently than un-parasitized nests, but this abandonment has a lower impact on the population since fewer parasitism events occur in these locations. It is not known what cowbird abundances exist in each region, to what level these abundances may drive parasitism or abandonment rates, or what can be done to control for this factor. Both Coryell Co. and Kerr have on-going cowbird trapping programs that have decreased parasitism rates in both regions (T. L. Pope, T. J. Conkling, unpublished data), but it is not known what previous abandonment levels existed for the vireo.

Nest Predation.—I observed varying predation rates across locations. This variability appears related to the nest predator assemblages at each location. In Coryell Co. snakes

and cowbirds depredated equal numbers of nests (n = 3) and together comprised 75% of identified predation events. In Kerr WMA, snakes predated nearly twice as many nests as cowbirds and western-scrub jays, although total avian predators combined to be the most frequent predator class (43.7%). At Devils River, avian species were also the most frequent nest predators (46.1%), followed by mammals (23%). Both snakes and ant spp. were responsible for the fewest nest predations. Additionally, ant predations (n = 2) at Devils River may not be fire ants, since the identified range for this species does not extend that far west.

The nest predator species I identified in this study provide a new insight into the identified major predators for the vireo. While snake predation rates at all sites combined were comparable to previous data from Ft. Hood (Stake and Cimprich 2003), this pattern was not observed in the Devils River region, where the arid environment may preclude rat snakes and instead nests may be more vulnerable to numerous other mammalian and avian predators. Ant species accounted for 16.1% of predation events across all locations; however these totals are ~50% lower than previous data at Ft. Hood. Additionally, cowbirds were twice as likely to be the nest predator as had previously been recorded. This discrepancy may result from differing land uses. Both privately owned properties and state-managed lands evaluated in this study are typically used for ranching and wildlife purposes. While Ft. Hood also maintains cattle grazing practices, it has the additional disturbance component of military training, incorporating multiple disturbances through heavy machinery and tanks. These disturbances may produce soil conditions favored by fire ants, making them more prevalent within Ft. Hood than on

other properties. Consequentially, the increased grazing and wildlife management practices that are frequent on the study properties may promote increased populations of cowbirds, thus increasing both the risk of parasitism and predation for vireo nests.

Vegetation Sampling.—Vireos were consistent with nest height and nest substrate height between locations, indicating vireos may have a preferred range of nest height, regardless of region. However, both distance to edge and concealment measurements at the nest differed significantly based on location. Although the shorter distance to edge is related to the smaller habitat clumps available within the southern part of the vireo's range, (and the concealment most likely related to the vegetation species in each region), this does not explain the preference for vireos in Coryell Co. to nest significantly further from the habitat edge. Vireos breeding further north could be selecting nest locations further from the edge since this vegetation may provide extra distance to reduce predation risk from snakes, or may be more likely to contain nesting substrate at the height and concealment preferred by vireos in the region.

Although samples at each location for the different predator species were small, the data indicates there may be a trend between specific vegetation characteristics and predator classes. I predicted that ant spp. would be more likely to depredate nests that were lower to the ground and closer to the habitat edge, since both foraging height and distance to the mound (often at habitat edges or disturbed habitat) would limit the frequency of ant predations. Ants depredated nests that were lower than mean height, at all locations, suggesting that ants systematically forage close to the ground and are more likely to encounter lower nests. Ant-depredated nests were also closer to the edge at

both Kerr and Devils River, which indicates ants may preferentially forage near the edge in those locations. However, the opposite was true in Coryell Co, where the 1 ant-predated nest was 8.0 m from the nearest habitat edge. Although fire ants were observed depredating this nest during a visual nest check, it was difficult to confirm ant species identification on video-recorded events. Other ant species have been observed depredating white-eyed vireo (*Vireo griseus*) in this region (Campomizzi et al. 2009), so it is possible that any of the observed ant predations may be species other than *Solenopsis invicta*, and may have different foraging patterns than *S. invicta*, the species I based my predictions on.

For both cowbirds and other avian species, I predicted that higher nests would be more likely to be predated, since avian predators would probably identify nests from perches located higher in the vegetation. I also predicted that frequency of predations would increase with distance from habitat edge, since avian predators in the region were less likely to be edge specialists. However, there were no significant vegetative differences noted for nests predated by cowbirds. When combining all nests affected by cowbirds by either parasitism or predation, the only significant value observed was nearest distance to habitat edge at Kerr. It is unclear what cues cowbirds are using to locate nests, since there were no indications that nest height, distance to edge, or concealment increased predation or parasitism risk at any other location. Nests depredated or parasitized by all avian predators combined demonstrated the same general pattern as cowbird-affected, with the only significant value for distance to nearest edge at Kerr. Like cowbirds nests, all nests with avian predators were

significantly further than the habitat edge than expected by chance. Kerr also had the largest number of avian predation events, so it is possible that predators are utilizing a search strategy to locate nests that differs from the other 2 locations where avian predators are not as prevalent.

I initially predicted that mammal spp. would be more likely to depredate nests that were lower to the ground, since nest height would limit accessibility, while frequency would increase with distance from habitat edge and decrease with an increase in nest concealment. However, for all identified mammal predation events, nest height was higher, while distance to edge was lower for both Kerr and Devils River (excluding outliers). This difference in nest height likely results from the presence of ringtails (*Bassariscus astutus*) at Devils River who accessed nests by climbing, as opposed to predicted predations from meso-carnivores at ground level, such as coyotes (*Canis latrans*).

The lack of recorded mammal predation events in Coryell Co. is not surprising, given the previous data collected on Ft. Hood, as well as the predator management strategies of private lands in county. On private properties in Texas, land owners often physically remove meso-carnivores since they are believed to be detrimental to livestock. The removal of these predators may explain the lack of recorded events involving these species.

I expected snake-predated nests to be lower than mean nest height, have less concealment, and to be closer to the habitat edge than expected by chance. This was true at all locations, especially for Coryell Co, where both nest height and distance to edge

were significantly less than was to be expected by chance. The presence of a relationship here may result from the large edge distance, which could limit the number of nests vulnerable to snakes in Coryell Co.

For cowbird effects on nest predation, I predicted that parasitized nests would have a lower frequency of nest predation than non-parasitized nests, resulting from cowbirds predating nests to promote re-nesting as stated in the "cowbird predation hypotheses" mentioned previously. I only recorded cowbirds predation events at non-parasitized nests, and predation events at all locations were at least twice as likely for non-parasitized nests compared to parasitized nests. However, these results were only statistically significant at Devils River. It is unclear what may be driving this relationship. Both Kerr and Coryell Co. have high abandonment rates, where most nests parasitized at these locations were later abandoned, and it is not known whether these nests would have been predated in the future had they remained active; however, this would not create the significant relationship detected here.

My data regarding the hypothesis of cowbird nest predation to promote future parasitism opportunities is also inconclusive, but does provide tentative evidence. Three of the 4 observed pairs who had cowbird predations did have a later nest parasitized, although it is unknown whether the cowbird female responsible for both predating and parasitizing nests of a given pair was the same individual. Two of these pairs later abandoned their parasitized nests, indicating that although this strategy of nest depredation may be beneficial for cowbirds in promoting future parasitism opportunities through host re-nesting, it would be better suited for host species who did not frequently

abandon parasitized nests. Thus, in the case of the vireo and the cowbird, it may be a lose-lose strategy for both species, since the host loses offspring through predation, and the cowbird loses offspring through host abandonment of the parasitized nest.

CHAPTER IV

SUMMARY OF MANAGEMENT IMPLICATIONS

MANAGEMENT IMPLICATIONS FOR CHAPTER II

My data suggest that the predator assemblages for both the black-capped vireo and white-eyed vireo differ from previously identified predator species, and that this difference may occur due to differing land and predator management strategies. The risk of nest depredation by snakes appears to increase with proximity to habitat edge. Therefore, managers should stress the importance of maintaining contiguous patches of vireo habitat to reduce fragmentation impacts. Regarding other identified nest predators, fire ant impacts on vireo nests on private lands may be less important than previously believed, despite their wide-spread occurrence. However, brown-headed cowbirds may have a greater impact than previously believed on nest success of both vireo species, indicating that further research is needed to determine effective management strategies for this predator. Additionally, while the nest success of vireos cannot be accurately predicted by the frequency of visits of potential predators (and other species), more information is needed to understand potential impacts of activity near vireo nests that could indirectly affect nesting vireos.

MANAGEMENT IMPLICATIONS FOR CHAPTER III

My data suggest that the predator assemblage for the black-capped vireo differs from previously identified predator species and that this difference may occur due to geographic location within the species' range and differing land management strategies.

Both nest site characteristics and nest predators varied by region, indicating that an all-inclusive management strategy may not be viable for species recovery, and that managers instead need to develop conservation plans on a localized scale. The risk of nest depredation by snakes appears to increase with proximity to habitat edge, especially in areas where large patches of vireo habitat exist. Therefore, managers should stress the importance of maintaining contiguous patches of habitat to reduce fragmentation impacts, especially in regions where snakes are the primary nest predator. Regarding other identified nest predators, fire ants impacts on vireo nests across the range may be less important than previously believed, despite their wide-spread occurrence. However, brown-headed cowbirds may have a greater impact than previously believed on nest success of black-capped vireo through both parasitism and predation. My results indicate that cowbirds may be predating nests to create future parasitism opportunities and that further research is needed to understand the mechanisms and rationale behind cowbird nest predation and to determine effective management strategies for this predator.

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